

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 09-172199

(43)Date of publication of application : 30.06.1997

(51)Int.Cl.

H01L 33/00

(21)Application number : 07-349727

(71)Applicant : MITSUBISHI CABLE IND LTD

(22)Date of filing : 20.12.1995

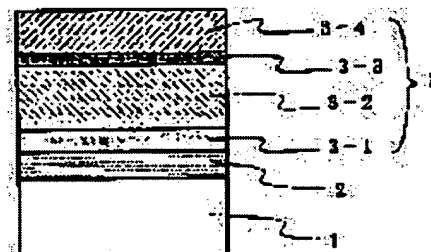
(72)Inventor : WATABE SHINICHI
TADATOMO KAZUYUKI

(54) GALLIUM NITRIDE COMPOUND SEMICONDUCTOR CHIP

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a gallium nitride group compound semiconductor chip excellent in productivity by laminating gallium nitride compound semiconductor layers on a substrate made of a high-melting point material having a melting point above a specific value through a buffer layer.

SOLUTION: Gallium nitride compound semiconductor layer 3 are formed on a substrate which is a glass substrate or a polycrystalline substrate made of a high-melting point material having a melting point above 1200° C through a buffer layer 2. ZnO is used for the buffer layer 2. And, as for the gallium nitride compound semiconductor layers 3, an AlN layer is used for a buffer 3-1, an Si-doped GaN layer is used for an n-type clad layer 3-2, a Zn-doped InGaN layer is used for an active layer 3-3 and an Mg-doped GaN layer is used for a p-type clad layer 3-4 respectively. Thereby, optical characteristics and electric characteristics of a chip can be improved.



LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

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CLAIMS

[Claim(s)]

[Claim 1] The gallium nitride system compound semiconductor element which is a glass substrate or a polycrystal substrate and is characterized by coming to carry out the laminating of the gallium nitride system compound semiconductor layer on the substrate which consists of a refractory material with a melting point of 1200 degrees C or more through a buffer layer.

[Claim 2] The gallium nitride system compound semiconductor element according to claim 1 whose above-mentioned buffer layer is the oxide of II group element.

[Claim 3] The gallium nitride system compound semiconductor element according to claim 1 or 2 whose above-mentioned buffer layer is ZnO.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the gallium nitride system compound semiconductor element excellent in productivity.

[0002]

[Description of the Prior Art] Current and a gallium nitride system compound semiconductor element are used as a light emitting device, a photo detector, and an electron device, and, specifically, are being used as LED, laser, a transistor, etc.

[0003] Generally, the semi-conductor layer of a single crystal comes to carry out the laminating of the above-mentioned gallium nitride system compound semiconductor element on a substrate. Conventionally, in order that a gallium nitride system compound semiconductor element might raise the crystallinity of a semi-conductor layer from the point of the optical property of a component, and electrical characteristics, single crystals, such as sapphire and silicon carbide, were used as a substrate. However, since they were single crystals, these had complicated manufacture conditions, and have long duration to grow up a single crystal even into the thickness which can be used as a substrate, and had the problem that productivity was bad. Since a semi-conductor layer comes to carry out the laminating of the gallium nitride system compound semiconductor element on a substrate, the badness of the productivity of a substrate also influences the productivity of a gallium nitride system compound semiconductor element.

[0004] This invention aims at offering the gallium nitride system compound semiconductor element excellent in productivity.

[0005]

[Means for Solving the Problem] This invention attains the above-mentioned purpose by the gallium nitride system compound semiconductor element which is a glass substrate or a polycrystal substrate and is characterized by coming to carry out the laminating of the gallium nitride system compound semiconductor layer on the substrate which consists of a refractory material with a melting point of 1200 degrees C or more through a buffer layer. Moreover, when the above-mentioned buffer layer is the oxide of II group element, the optical property and electrical property of a component can be improved. Moreover, when the above-mentioned buffer layer is ZnO, the optical property and electrical property of a component can be improved further.

[0006] Specifically in this invention, a glass substrate or a polycrystal substrate is used using what excelled the single crystal substrate in productivity. Moreover, the ingredient used for the gallium nitride system semi-conductor layer by which a laminating is carried out on a substrate in this invention has the high melting point, and since crystal growth of a semi-conductor layer will be performed at an about 1000-degree C elevated temperature, as for an above-mentioned glass substrate or an above-mentioned polycrystal substrate, the melting point consists of a refractory material 1200 degrees C or more.

[0007] The glass substrate in this invention does not have a spectrum peak in an X diffraction. As an ingredient of the glass substrate used for this invention, if the melting point is 1200 degrees C or more, the thing of amorphous conditions, such as quartz glass which especially a limit does not have, for example,

consists of a silicon dioxide 100% glass which contains oxides, such as 3 oxides in 2 boron, a calcium oxide, and an aluminum oxide, by using a silicon dioxide as a principal component and silicon, and gallium nitride, etc. will be mentioned. There is especially no limit as the production approach of the above-mentioned glass substrate, for example, a vacuum arc heating decarbonizing process (Vapor-phase Axial Deposition) etc. is mentioned.

[0008] Moreover, the polycrystal substrate in this invention is what is created by the sintering process or the recrystallizing method, it is what has a peak from the crystal face where plurality differs for example, in an X diffraction spectrum, or that whose spectrum full width at half maximum is 0.5 degrees or more is mentioned in an X diffraction. As a polycrystal substrate in this invention, if the melting point consists of a refractory material 1200 degrees C or more, there will be especially no limit, for example, polycrystalline silicon, a polycrystal alumina, a polycrystal magnesia, etc. will be mentioned. Especially a limit does not have the thickness of the above-mentioned glass substrate or a polycrystal substrate, and it is usually about 100–500 micrometers.

[0009] In this invention, in order to use a glass substrate and a polycrystal substrate, without using a single crystal substrate, if the laminating of the direct semi-conductor layer is carried out on a substrate, the crystallinity of a gallium nitride system compound semiconductor layer will get worse remarkably. Therefore, in order to prevent it, it is necessary to mind a buffer layer between a substrate and a semi-conductor layer in this invention. This buffer layer consists of a good ingredient of a crystal stacking tendency, and, specifically, the spectrum full width at half maximum is a thing 0.5 degrees or less in an X diffraction. As an ingredient of a buffer layer used by this invention, the oxide of II group element excellent in the crystal stacking tendency is suitable. As an oxide of II group element, BeO, MgO, CaO, ZnO, SrO, CdO, BaO, HgO, etc. are mentioned, and ZnO, BaO, and HgO are suitably used especially from the point that the crystal structure is the same as a gallium nitride system compound semiconductor, and crystalline improvement in a semi-conductor layer can be desired also in the oxide of the above-mentioned II group element, for example. As an ingredient of a buffer layer used by this invention, you may be the compound which consists of the one above-mentioned sort or two sorts or more, and especially the compound therefore shown by the bottom formula which consists of the three above-mentioned kinds of oxides as an ingredient of a buffer layer used by this invention is suitable. What is necessary is just to set up a presentation ratio suitably according to the ingredient used for a semi-conductor layer.

$(\text{BeO})_X (\text{ZnO})_Y (\text{HgO})_{1-X-Y}$ (however, it is $0 \leq x \leq 1$, $0 \leq y \leq 1$, and $x+y \leq 1$)

[0010] There is especially no limit as the laminating approach of a buffer layer. For example, sputtering, A CVD method (Chemical Vapor Deposition: chemical-vapor-deposition method), the ion cluster beam method and MOVPE -- law (Metal Organic Vapor Phase Epitaxy: organic metal vapor-phase-epitaxial-growth method) -- The HVPE method (Hydride Vapor Phase Epitaxy: hydride vapor-phase-epitaxial-growth method), The MBE method (MolecularBeam Epitaxy: molecular beam epitaxy), It is desirable for the GS-MBE method (gas source MBE grown method), CBE (chemical beam epitaxial grown method), etc. to be mentioned, and to carry out a laminating by sputtering especially from the point of productivity. Although especially a limit does not have buffer layer thickness, about 0.01–2 micrometers is desirable, and about 0.02–1.5 micrometers is suitable especially from the crystalline point of the semi-conductor layer which carries out a laminating on a buffer layer. When buffer layer thickness exceeds less than 0.01 micrometers or 2 micrometers, it is in the inclination for the crystallinity of a semi-conductor layer to fall.

[0011] Moreover, as an ingredient of a gallium nitride system compound semiconductor layer used by this invention, if usually used, there will be especially no limit, for example, a GaN system ingredient, an AlGaIn system ingredient, an InGaIn system ingredient, an InGaAlN system ingredient, etc. will be mentioned. Moreover, if the structure of a gallium nitride system compound semiconductor layer forms a light emitting device, a photo detector, and the gallium nitride system compound semiconductor element used as an electron device, there will be especially no limit. For example, although double hetero structure is in one of the structures of the semi-conductor layer of the gallium nitride system compound semiconductor element used as a light emitting device, the semi-conductor layer of this double hetero structure usually consists of a buffer layer, n mold cladding layer, a barrier layer, and a p mold cladding layer.

[0012] Each class makes a single crystal come to grow up with the ingredient suitably chosen from the above in the above-mentioned double hetero structure. For example, AlN, GaN, etc. can be used for the buffer layer of a semi-conductor layer. Moreover, although the ingredient of n mold cladding layer and p mold cladding layer is determined by the ingredient used for a barrier layer The AlGaIn system ingredient expressed with $\text{Al}_x\text{Ga}_{1-x}\text{In}_y\text{N}$ ($0 \leq x \leq 1$), The InGaIn system ingredient expressed with $\text{In}_x\text{Ga}_{1-x}\text{In}_y\text{N}$ ($0 \leq x \leq 1$), the InGaAlIn system ingredient expressed with $\text{In}_x\text{Ga}_y\text{Al}_{1-x-y}\text{N}$ ($0 \leq x \leq 1$, $0 \leq y \leq 1$, $0 \leq x+y \leq 1$), GaN, etc. can be used. The ingredient used for a barrier layer is determined by the luminescence wavelength of the component to produce, and the InGaIn system ingredient expressed with $\text{In}_x\text{Ga}_{1-x}\text{In}_y\text{N}$ ($0 \leq x \leq 1$), GaN, etc. can be used for it. Moreover, in order [for conduction control] to establish an emission center, the dopant is doped by each class of the above-mentioned n mold cladding layer, a barrier layer, and p mold cladding layer, as this dopant, Si, germanium, etc. are used for n mold cladding layer, Zn, Mg, Cd, Be, etc. are usually good, and Zn, Cd, Si, etc. are used for p mold cladding layer at the barrier layer, for example. In addition, for about 0.01–0.1 micrometers and n mold cladding layer, about 2–6 micrometers and a barrier layer are [a buffer layer / about 0.001–0.1 micrometers and p mold cladding layer of the thickness of above-mentioned each class] usually about 0.3–1.5 micrometers.

[0013] In this invention as the laminating approach of the above-mentioned gallium nitride system compound semiconductor layer usually — if it is what is used — especially — a limit — there is nothing — for example, MOVPE — law (Metal Organic Vapor Phase Epitaxy: organic metal vapor-phase-epitaxial-growth method) — The HVPE method (Hydride Vapor Phase Epitaxy: hydride vapor-phase-epitaxial-growth method), The LPE method (Liquid Phase Epitaxy: liquid phase epitaxy), The MBE method (Molecular Beam Epitaxy: molecular beam epitaxy), the GS-MBE method (gas source MBE law), CBE (chemical beam epitaxial grown method), etc. are mentioned.

[0014] The gallium nitride system compound semiconductor element of this invention can be used as a light emitting device, a photo detector, and an electron device by setting up the structure of a semi-conductor layer suitably. As the application, LED, laser, a ultraviolet sensor, a transistor, etc. are mentioned, for example.

[0015] [Embodiment of the Invention] An example of the structure of a gallium nitride system compound semiconductor element is shown in drawing 1 as one embodiment of this invention. An example of the production approach of the gallium nitride system compound semiconductor element of drawing 1 is explained below. In addition, in this example, a gallium nitride system compound semiconductor layer is made to use the GaN layer which carried out Mg dope of the InGaIn layer which carried out Zn dope of the GaN layer which carried out Si dope of the AlN layer to n mold cladding layer at the barrier layer at p mold cladding layer, respectively at a buffer layer at a buffer layer using ZnO, using quartz glass in a substrate.

[0016] First, the quartz-glass substrate was produced by the vacuum arc heating decarbonizing process. Next, the quartz-glass substrate was put in in the sputtering system, and the spatter ingredient was made to carry out the laminating of the ZnO buffer layer by the thickness of 0.1 micrometers on a substrate on condition that the substrate temperature of 300 degrees C, incidence power 150W, and pressure 3mmTorr using ZnO. Then, the laminating of the gallium nitride system compound semiconductor layer was carried out on the above-mentioned buffer layer by the MOVPE method. It is as [detailed] follows. First, the quartz-glass substrate to which the laminating of the above-mentioned ZnO buffer layer was carried out is put into the growth interior of a room, substrate temperature is made into 1050 degrees C, and heat treatment is performed for 10 minutes. Next, substrate temperature is lowered at 500 degrees C, and it is trimethylaluminum at the flow rate of 30 cc/min NH_3 It passes to the growth interior of a room by the flow rate of 4 l/min, respectively, and 0.3 micrometers of AlN buffer layers are grown up. Next, the temperature up of the substrate temperature is carried out to 1020 degrees C, and it is trimethylgallium (TMG) 50 cc/min and NH_3 4 l/min and SiH_4 A sink and about 3 micrometers of n mold cladding layers of the Si dope GaN are grown up into the growth interior of a room by the flow rate of 30 cc/min, respectively. Then, substrate temperature is lowered at 700 degrees C, and they are 200 cc/min and TMG about trimethylindium 40 cc/min and NH_3 4 l/min and dimethyl zinc grow up 0.01 micrometers of barrier layers of a sink and Zn dope $\text{In}_{0.2}\text{Ga}_{0.8}\text{N}$ into the growth interior of a room by the flow rate of 10 cc/min, respectively. Finally the temperature up of the

substrate temperature is carried to 1020 degrees C, and it is TMG 50 cc and NH₃ 4l. / min, and bis (cyclopentadienyl) magnesium grew up a sink and 0.8 micrometers of p mold cladding layers of the Mg dope GaN into the growth interior of a room by the flow rate of 20 cc/min, respectively.

[0017]

[Example]

(Example 1) When carrier concentration estimated the electrical property of the gallium nitride system compound semiconductor element which used quartz glass (melting point of 1500 degrees C) for the substrate, used ZnO (spectrum full width at half maximum of 0.1 degrees in an X diffraction) for the buffer layer, and was produced on the same conditions as the above, the carrier concentration of n mold cladding layer was $1 \times 10^{18} \text{cm}^{-3}$, and the carrier concentration of p mold cladding layer was $1 \times 10^{17} \text{cm}^{-3}$.

(Example 2) When carrier concentration estimated the electrical property of the gallium nitride system compound semiconductor element produced on the same conditions as the above except having used for the substrate the polycrystalline silicon (melting point of 1420 degrees C) produced with the sintering process, the carrier concentration of n mold cladding layer was $1 \times 10^{18} \text{cm}^{-3}$, and the carrier concentration of p mold cladding layer was $1 \times 10^{17} \text{cm}^{-3}$.

[0018]

[Effect of the Invention] The gallium nitride system compound semiconductor element of this invention is a glass substrate or a polycrystal substrate, and can obtain the gallium nitride system compound semiconductor element excellent in productivity by coming to carry out the laminating of the gallium nitride system compound semiconductor layer on the substrate which consists of a refractory material with a melting point of 1200 degrees C or more through a buffer layer. Moreover, when the above-mentioned buffer layer is the oxide of II group element, the optical property and electrical property of a component can be improved. Moreover, when the above-mentioned buffer layer is ZnO, the optical property and electrical property of a component can be improved further.

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TECHNICAL FIELD

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EFFECT OF THE INVENTION

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TECHNICAL PROBLEM

[Description of the Prior Art] Current and a gallium nitride system compound semiconductor element are used as a light emitting device, a photo detector, and an electron device, and, specifically, are being used as LED, laser, a transistor, etc.

[0003] Generally, the semi-conductor layer of a single crystal comes to carry out the laminating of the above-mentioned gallium nitride system compound semiconductor element on a substrate. Conventionally, in order that a gallium nitride system compound semiconductor element might raise the crystallinity of a semi-conductor layer from the point of the optical property of a component, and electrical characteristics, single crystals, such as sapphire and silicon carbide, were used as a substrate. However, since they were single crystals, these had complicated manufacture conditions, and have long duration to grow up a single crystal even into the thickness which can be used as a substrate, and had the problem that productivity was bad. Since a semi-conductor layer comes to carry out the laminating of the gallium nitride system compound semiconductor element on a substrate, the badness of the productivity of a substrate also influences the productivity of a gallium nitride system compound semiconductor element.

[0004] This invention aims at offering the gallium nitride system compound semiconductor element excellent in productivity.

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MEANS

[Means for Solving the Problem] This invention attains the above-mentioned purpose by the gallium nitride system compound semiconductor element which is a glass substrate or a polycrystal substrate and is characterized by coming to carry out the laminating of the gallium nitride system compound semiconductor layer on the substrate which consists of a refractory material with a melting point of 1200 degrees C or more through a buffer layer. Moreover, when the above-mentioned buffer layer is the oxide of II group element, the optical property and electrical property of a component can be improved. Moreover, when the above-mentioned buffer layer is ZnO, the optical property and electrical property of a component can be improved further.

[0006] Specifically in this invention, a glass substrate or a polycrystal substrate is used using what excelled the single crystal substrate in productivity. Moreover, the ingredient used for the gallium nitride system semiconductor layer by which a laminating is carried out on a substrate in this invention has the high melting point, and since crystal growth of a semi-conductor layer will be performed at an about 1000-degree C elevated temperature, as for an above-mentioned glass substrate or an above-mentioned polycrystal substrate, the melting point consists of a refractory material 1200 degrees C or more.

[0007] The glass substrate in this invention does not have a spectrum peak in an X diffraction. As an ingredient of the glass substrate used for this invention, if the melting point is 1200 degrees C or more, the thing of amorphous conditions, such as quartz glass which especially a limit does not have, for example, consists of a silicon dioxide 100%, glass which contains oxides, such as 3 oxidation 2 boron, a calcium oxide, and an aluminum oxide, by using a silicon dioxide as a principal component and silicon, and gallium nitride, etc. will be mentioned. There is especially no limit as the production approach of the above-mentioned glass substrate, for example, a vacuum arc heating decarbonizing process (Vapor-phase Axial Deposition) etc. is mentioned.

[0008] Moreover, the polycrystal substrate in this invention is what is created by the sintering process or the recrystallizing method, it is what has a peak from the crystal face where plurality differs for example, in an X diffraction spectrum, or that whose spectrum full width at half maximum is 0.5 degrees or more is mentioned in an X diffraction. As a polycrystal substrate in this invention, if the melting point consists of a refractory material 1200 degrees C or more, there will be especially no limit, for example, polycrystalline silicon, a polycrystal alumina, a polycrystal magnesia, etc. will be mentioned. Especially a limit does not have the thickness of the above-mentioned glass substrate or a polycrystal substrate, and it is usually about 100-500 micrometers.

[0009] In this invention, in order to use a glass substrate and a polycrystal substrate, without using a single crystal substrate, if the laminating of the direct semi-conductor layer is carried out on a substrate, the crystallinity of a gallium nitride system compound semiconductor layer will get worse remarkably. Therefore, in order to prevent it, it is necessary to mind a buffer layer between a substrate and a semi-conductor layer in this invention. This buffer layer consists of a good ingredient of a crystal stacking tendency, and, specifically, the spectrum full width at half maximum is a thing 0.5 degrees or less in an X diffraction. As an ingredient of a buffer layer used by this invention, the oxide of II group element excellent in the crystal stacking tendency is suitable. As an oxide of II group element, BeO, MgO, CaO, ZnO, SrO, CdO, BaO, HgO, etc. are mentioned, and

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$(\text{BeO})_X (\text{ZnO})_Y (\text{HgO})_{1-X-Y}$ (however, it is $0 \leq x \leq 1$, $0 \leq y \leq 1$, and $x+y \leq 1$)

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[0016] First, the quartz-glass substrate was produced by the vacuum arc heating decarbonizing process. Next, the quartz-glass substrate was put in in the sputtering system, and the spatter ingredient was made to carry out the laminating of the ZnO buffer layer by the thickness of 0.1 micrometers on a substrate on condition that the substrate temperature of 300 degrees C, incidence power 150W, and pressure 3mmTorr using ZnO. Then, the laminating of the gallium nitride system compound semiconductor layer was carried out on the above-mentioned buffer layer by the MOVPE method. It is as [detailed] follows. First, the quartz-glass substrate to which the laminating of the above-mentioned ZnO buffer layer was carried out is put into the growth interior of a room, substrate temperature is made into 1050 degrees C, and heat treatment is performed for 10 minutes. Next, substrate temperature is lowered at 500 degrees C, and it is trimethylaluminum at the flow rate of 30 cc/min NH3 It passes to the growth interior of a room by the flow rate of 4 l/min, respectively, and 0.3 micrometers of AlN buffer layers are grown up. Next, the temperature up of the substrate temperature is carried out to 1020 degrees C, and it is trimethylgallium (TMG) 50 cc/min and NH3 4 l/min and SiH4 A sink and about 3 micrometers of n mold cladding layers of the Si dope GaN are grown up into the growth interior of a room by the flow rate of 30 cc/min, respectively. Then, substrate temperature is lowered at 700 degrees C, and they are 200 cc/min and TMG about trimethylindium 40 cc/min and NH3 4 l/min and dimethyl zinc grow up 0.01 micrometers of barrier layers of a sink and Zn dope In_{0.2}Ga_{0.8}N into the growth interior of a room by the flow rate of 10 cc/min, respectively. Finally the temperature up of the substrate temperature is carried out to 1020 degrees C, and it is TMG 50 cc/min and NH3 4l. / min, and bis (cyclopentadienyl) magnesium grew up a sink and 0.8 micrometers of p mold cladding layers of the Mg dope GaN into the growth interior of a room by the flow rate of 20 cc/min, respectively.

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EXAMPLE

[Example]

(Example 1) When carrier concentration estimated the electrical property of the gallium nitride system compound semiconductor element which used quartz glass (melting point of 1500 degrees C) for the substrate, used ZnO (spectrum full width at half maximum of 0.1 degrees in an X diffraction) for the buffer layer, and was produced on the same conditions as the above, the carrier concentration of n mold cladding layer was $1 \times 10^{18} \text{cm}^{-3}$, and the carrier concentration of p mold cladding layer was $1 \times 10^{17} \text{cm}^{-3}$.

(Example 2) When carrier concentration estimated the electrical property of the gallium nitride system compound semiconductor element produced on the same conditions as the above except having used for the substrate the polycrystalline silicon (melting point of 1420 degrees C) produced with the sintering process, the carrier concentration of n mold cladding layer was $1 \times 10^{18} \text{cm}^{-3}$, and the carrier concentration of p mold cladding layer was $1 \times 10^{17} \text{cm}^{-3}$.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is an example of the structure of the gallium nitride system compound semiconductor element of this invention.

[Description of Notations]

- 1: Substrate
- 2: Buffer layer
- 3: Gallium nitride system semi-conductor layer
- 3-1: Buffer layer
- 3-2: n mold cladding layer
- 3-3: Barrier layer
- 3-4: p mold cladding layer

[Translation done.]

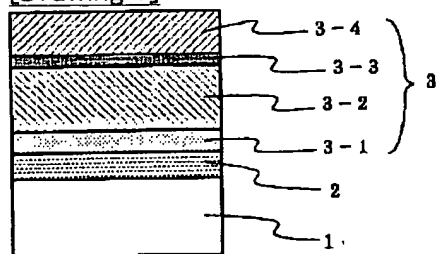
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DRAWINGS

[Drawing 1]



[Translation done.]